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The Interest of the Wind Farm of Adrar to the Southwest Network of Algeria

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A B S T R A C T

The interest in renewable energy has been increasing over the last few years, especially after global awareness regarding the hazardous effect of fossil fuel burning. Energy is the source of growth and the booster of the economic and social development of nations and people. This issue has prompted the Algerian government to adopt a new energy policy by promoting and supporting the development of the clean energy, specially the wind and solar energy. An important result of this policy is that the government intended to construct a wind farm in the southwest desert of Algeria. This paper shows the interest of this investment for the southwest region of Algeria, which is installed in Teberkine in Adrar city with an High Voltage Direct Current (HVDC) connection to improve the power quality in this region without disturbing the network. The open source software Power System Analysis Toolbox (PSAT) is used in our simulations to improve the calculations.

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INTRODUCTION

Energy is the source of growth and it drives the economic and social development of nations [1]. Algeria has significant resources of renewable energy namely the inexhaustible solar radiation that covers an area of 2,381,745km^2, with more than 3000 hours of sunshine per year and the existence of a significant wind energy potential [2]. In March 2011, Algerian government has started an ambitious project "efficiency program for renewable energy". The Algerian Ministry of Energy and Mines has planned to produce 22000 MW from strictly green energy sources [3]:

- 12000 MW to meet domestic electricity demand;
- 10000 MW for export.

According to Naimi et al. [4], considering the wind's energy potential, Algeria ranks the 5th among fifteen African countries. The first wind farm in Algeria has been built in Adrar city (southwest region of Algeria). It generates 10MW of electricity which will be integrated in the Algerian network [5]. The fact that Adrar city is not yet connected to the Algerian southwest network, motivated us to study the means and the interest of the wind farm connection to Algeria's southwest network. Therefore, it is imperative to understand the new aspects when integrating the wind energy that has been brought to the southwest region of Algeria.

This paper consists of two parts, the first part concerning the presentation of the wind farm installed in Adrar and the climatic conditions of this region; whereas, the second part is dedicated to the model simulations, in which, the interest of connecting the wind farm with the Algerian southwest network is illustrated in the folowing figures. Due to the fact that isolated network of Adrar is too disturbed, the study investigates how to reduce risks from Adrar's network using the HVDC connection.

THE WIND FARM OF ADRAR

Adrar departement is located in the southwest of Algeria as shown in Figure 1 has a yearly average wind speed of more than 6m/s [6]. These remote areas are characterized by Drillings and Kessours where the network connection is impossible or very expensive; as a result, producers were forced to use the wind energy to produce electricity [7].

The new generation of power plant or the wind farm has a capacity of 10 megawatts, it is located about 72km north of the Adrar city. It consists of 12 wind turbines each one with 0.85MW. The turbines of small and medium powers in three ranges [8]:

- Micro-wind turbines: a range of nominal power of 20W to 500W;
- Mini wind turbines: a range of nominal power of 500W to 1kW;
- Small Wind: from 1kW to 100kW.

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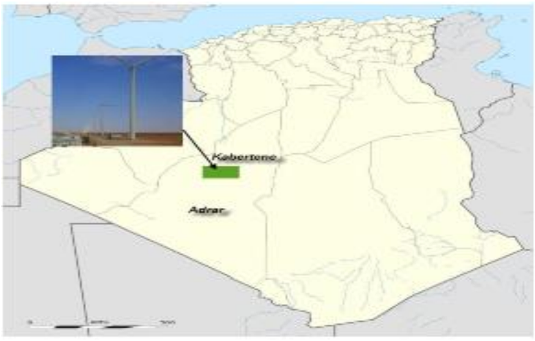

Figure 1. The wind farm of Adrar allocation

Adrar allocation

The Algerian wind data map measured at 10m above the ground level, established in 2018 by Daaou Nedjari et al. [9] shows that a maximum average wind speed is reached in a Southwest (Adrar region) of the country with a value of 6.5m/s as is presented in Figure 2.

The Adrar's network consists of two electric lines connecting Adrar to other cities the first 274km and the second 190km. The network also has 3142km medium voltage lines and 1,400 km low voltage. This region is mainly supplied through a gas power plant (115MW) located in the same city, and also by other small power plants (13.26MW), knowing that the demand for electricity continues to increase by 5% per year. Figure 2 shows the wind speed at 10m from the ground; we can observe that Adarar has a very good wind speed higher than 6.5m/s [10].

Wind power model

Several previous works [11, 12] have shown that there is no appropriate mathematical model to all types of wind turbines. However, the quadratic model has generally the lowest quadratic error which seems to be promising to test most turbines. The model presented in literature [13-16] is chosen to determine the produced power through the wind speed P_{ge}, which is described as follows:

$$P_{ge}(v) = P_{n.ge}\frac{v_2 - v_{d2}}{v_{n2} - v_{d2}} \qquad v_d < v < v_n \qquad (1)$$

$$P_{ge}(v) = P_{n.ge} \qquad v_d < v < v_c \qquad (2)$$

$$P_{ge}(v) = 0 \qquad v < v_d \text{ and } v \geq v_c \qquad (3)$$

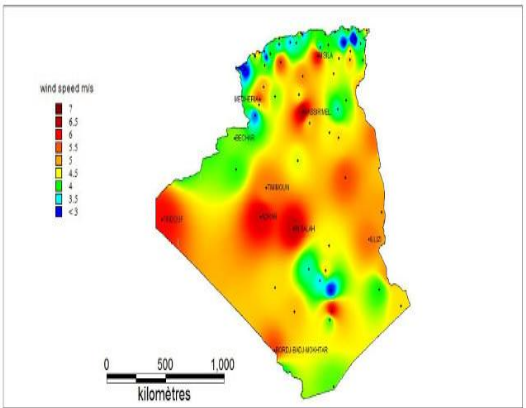

Figure 2. Wind atlas of Algeria at 10 m from the ground [8]

where $P_{n.ge}$ is the nominal power of the wind, v is the wind speed at height hub. v_d, v_n and v_c are the start up speed, the speed corresponding to the rated power of the machine and shutdown speed, respectively. This model is used to estimate the output power of four wind turbines (N29/250, N43/600, N54/1000 and N60/1300) provided by the manufacturers [17].

HVDC CONNECTION

50 years ago in Sweden, the first commercial HVDC connection was installed by ABB group (ASEA Brown Boveri). Since then, over a hundred HVDC transmission systems have been achieved in the world. HVDC differs from high voltage alternative current (HVAC), in that the voltage is not alternating at 50 or 60 cycles per second but it is constant [18].

After more than 50 years of research and development, HVDC transmission systems now transport energy in many countries and are marked by increases over time of the power, the length of the connection and the operating voltage [19].

The main function of an HVDC connection is the transportation of electrical energy, with a minimum of losses, from sources of energy to load centres, usually separated by long distances. Losses are only 3% per 1000 km at a standard cost (losses can be further reduced to 0.3% per 1000km but at a higher cost). Possible applications include: [20]

- Connect wind farms to electricity networks.
- Underground electrical connections.
- Connected asynchronous connections (frequency difference).

Another advantage of HVDC links is that the cost of DC lines and cables is reduced [21]:

- Two conductors (and sometimes only one) instead of three in AC.
- In DC, there are no loss of skin effect and dielectric loss.
- The joules effect losses are 25% lower in DC, for the same transited power, by comparing an AC line with three-conductors and a two-conductor DC line [22].

As a result, the DC line is more economical. Also, the DC link does not consume reactive power.

SIMULATION AND RESULTS

The network connection to Adrar department

The Algerian southwest power supply network is considered in this study, it operates at 60kV and 220kV. The transmission system consists approximately of 2000km of 11 lines and transmission substations. It contains 15 buses, 16 lines, 11 transformers, 02 generators and 11 loads. The full grid is shown in Figure 3.

Due to the fact that the electrical lines in the network is too long, for instance we have a 220kV line between Saida and Naama stretching for 220km long and another one of 220kV Naama and Bechar for a distance of 320km. There is also a 60kV line that exceeds 200km. There is no power plant in this region except the power plant of Naama, for this reason, the region is almost supplied by Saida. This last one is powered by two lines of 220kV, the first one comes from Tiaret power plant and the second one comes from Terga power plant through Sidi ali boussidi sub-station.

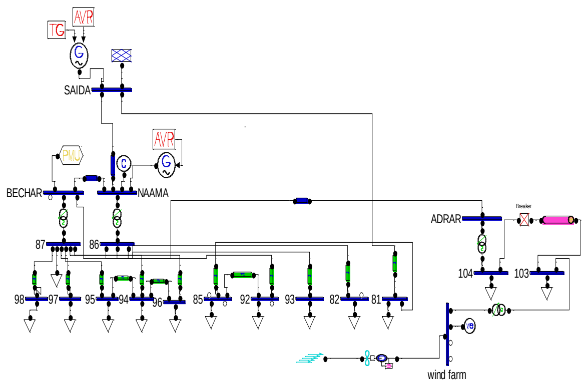

Figure 3. The southwest electrical network of Algeria connected to Adrar

Therefore, the main problem in this region is the voltage drop, which can be solved by several methods like:

- The construction of a new power plant in Bechar city.
- The interconnection with Morocco network at the point Feguig-Beni Unif.
- The connection of this region to Adrar department.

The first and second solutions are rejected in the future due to some political and economic problems, therefore the third solution is adopted to the problem of voltage drop in the southwest region of Algeria, in addition to benefit from the wind farm that exists in Adrar department.

We connected the southwest region of Algeria with a line of 220kV and a circuit breaker as shown in Figure 3. At the beginning, we connected this line, at the time t=5s, the circuit breaker line is opened to see the effect of this connection on the voltages nodes. Some nodes are chosen as samples, see Figures 4, 5 and 6.

We can see that the nodal voltages of Bechar city, buses numbers 85 and 92 have a good quality after opening circuit breaker, but when disconnecting the wind farm Adrar city the voltages levels in these buses are degrade. For example, Figure 4 shows the nodal voltage of Bechar bus, it is noted that the voltage was 1.1pu before opening the circuit breaker i.e. when the southwest region is connected to Adrar. After opening the circuit breaker and isolating Adrar's department with its wind farm the voltage drops to 1.0pu.

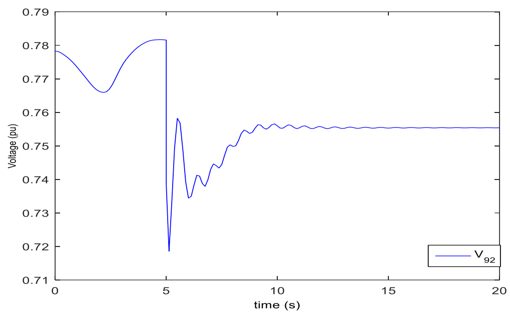

Figure 6. The voltage at number 92

The perturbation

We connected the network southwest of Algeria with the wind farm that exists at Adrar and then we improved the voltage levels in the network, unfortunately from Sonelgaz (company that manages electrical networks in Algeria) the network of Adrar is too disturbed by the faults. If we connect the southwest region to Adrar network, we improved the voltages levels but we infect this network by perturbations. Then we will try to solve this problem, why not in the same network of Adrar city the fault is applied at t = 5s and we increased the duration of the fault until arrive at critical time, t = 6.18s. The voltages levels of some buses in the network are shown in Figures 7, 8, 9 and 10.

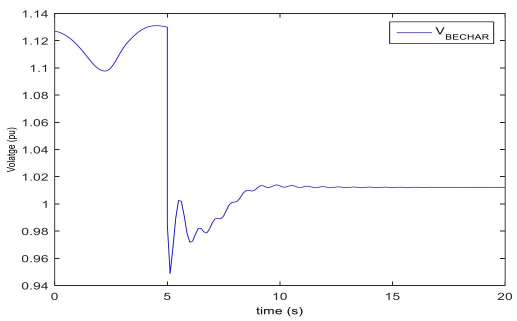

Figure 4. The voltage at bus of Bechar city

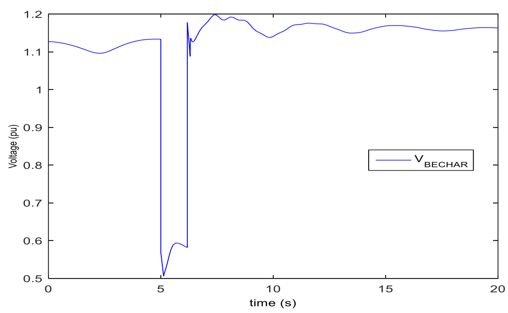

Figure 7. The voltage at bus of Bechar with fault at t=5s

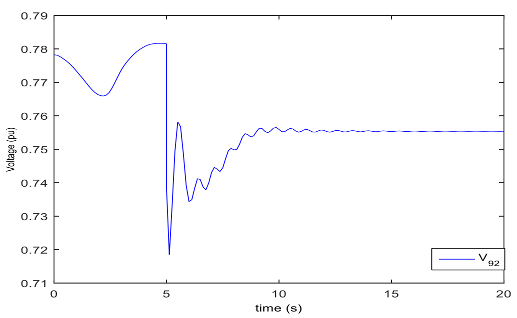

Figure 5. The voltage at number 85

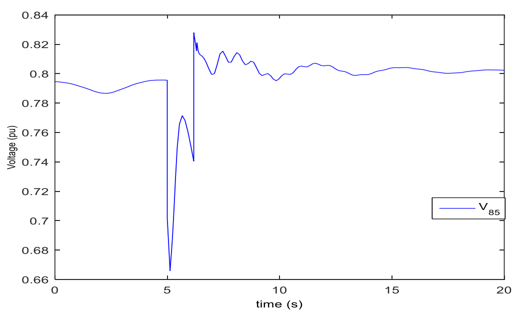

Figure 8. Voltage at bus 85 with fault at t=5s

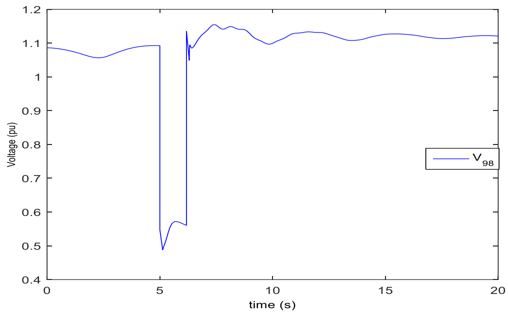

Figure 9. The voltage at bus 98 with fault at t=5s

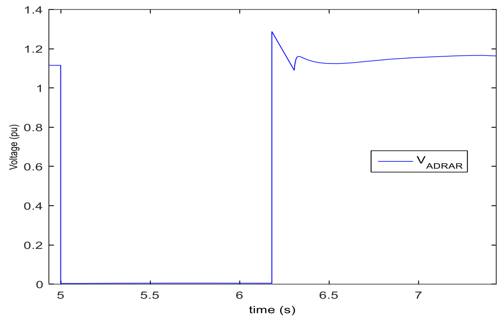

Figure 10. Voltage at bus of Adrar with fault at t=5s

If we increase the duration beyond 6.18s, i.e. beyond the critical time we have a blackout throughout the network as shown in Figures 11,12 and 13.

We continue with the same node which is that of Bechar in the Figure11, when we increase the time of removal of the fault which is t = 6.18 s, the voltage droops from 1.1pu to 0.5pu and remains in the same level , it is the blackout.

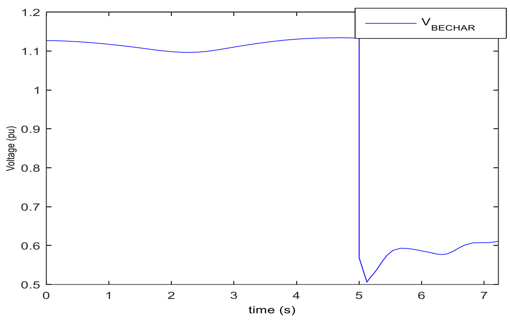

Figure 11. The blackout at bus of Bechar after 6.18s

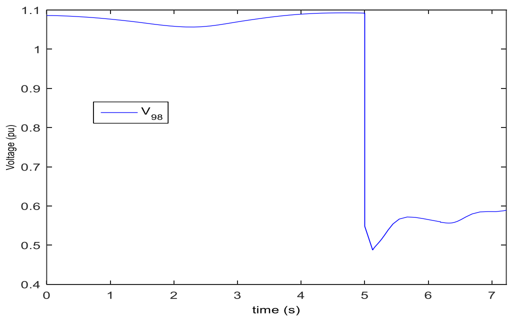

Figure 12. The blackout at bus 98 after 6.18s

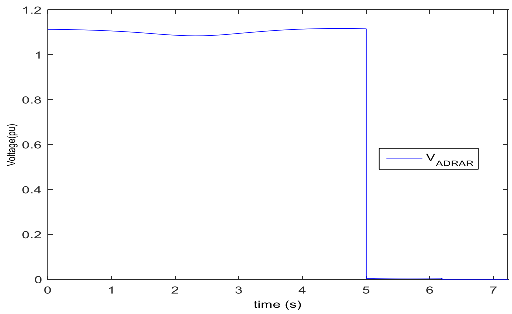

Figure 13. The blackout at bus of Adrar after 6.18s

We can say that our network can support up to 1.18 second after that it's the blackout. To solve this problem, we made use the HVDC connection between Adrar and the southwest network of Algeria shown in Figure 14.

This solution has two advantages, the first one solves the problem of the distance between Adrar and the southwest network and the second one increases the critical time to avoid the blackout.

We apply the same fault at the same time in the same place in Adrar of Figure 17, we have the levels of nodal voltages of buses, taken before, which are shown in Figures 15, 16 and 17.

For the Bechar node Figure 15, the fault has been applied at t = 5s has lasted until t = 7.6s, ie a duration of 2.6 seconds without the network falling into the blackout is back to normal operation.

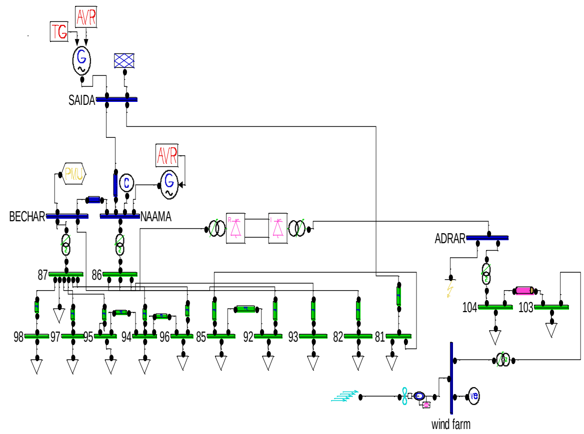

Figure 14. The southwest network of Algeria with HVDC connection

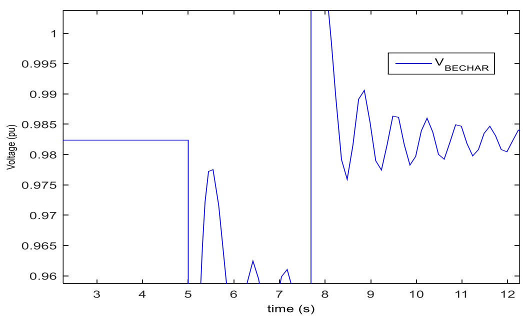

Figure 15. The voltage at bus of Bechar with HVDC connection

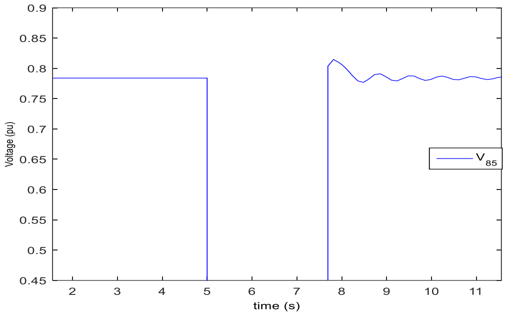

Figure 16. The voltage at bus 85 with HVDC connection

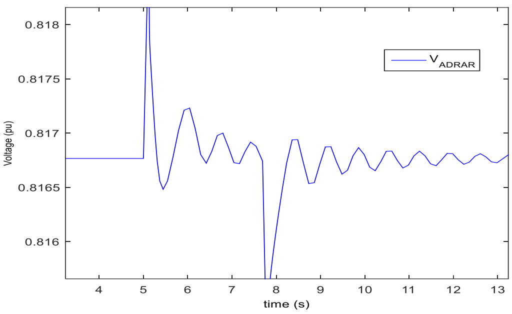

Figure 17. The voltage at bus of Adrar with HVDC connection

CONCLUSION

In this paper, the ability of renewable energy and HVDC technology merging is proposed to improve the quality of the power network. The simulation study was based on a real network topology of the southwest region of Algeria. The renewable energy is used to improve the voltage quality of the southwest electrical network. The HVDC is used to ensure a good integration of the wind farm of Adrar in the south-west Algerian network by avoiding the blackout and reduce the losses in this region.

The obtained results show that renewable energy and HVDC technologies can contribute effectively to improve the quality of the voltage at several buses, also to the integration of the wind power into the network and therefore they will play a vital role in the future power grids.

The obtained results show also that the HVDC connection plays an important role not only to carry a large amount of power, but also to better control and protect power grids in order to avoid the blackout.

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Persian Abstract

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چکیده

میل به استفاده از انرژی‌های تجدیدپذیر در طول چند سال گذشته افزایش یافته است، به ویژه پس از آگاهی جهانی در مورد اثر مخرب سوخت‌های فسیلی از انرژی تجدیدپذیر استقبال خوبی بعمل آمده است. انرژی منبع رشد و تقویت رشد اقتصادی و اجتماعی ملل و مردم محسوب می‌شود. این موضوع موجب شده است دولت الجزایر با ترویج و حمایت از توسعه انرژی پاک، سیاست جدید انرژی را اتخاذ کند. نتیجه مهم از این سیاست این است که دولت قصد دارد یک مزرعه باد در صحرای جنوب غربی الجزایر را بسازد. این مقاله علاقه این سرمایه‌گذاری برای منطقه جنوب غربی الجزایر، که در Teberkine در شهر Adrá با HVDC (ولتاژ جریان مستقیم) نصب شده است برای بهبود کیفیت قدرت در این منطقه بدون مزاحمت شبکه را نشان می‌دهد. نرم‌افزار منبع باز جعبه ابزار تجزیه و تحلیل قدرت (PSAT) در شبیه‌سازی‌های ما برای بهبود محاسبات استفاده می‌گردد.